doi: 10.25923/cgd6-pq50

Cruise Report: EX-14-04 Legs 2 & 3 Our Deepwater Backyard: Exploring Atlantic Canyons and Seamounts (ROV and Mapping)

Northwest Atlantic

Leg 2: North Kingstown, RI, to Baltimore, MD
(04, September, 2014 — 10, September, 2014)

Leg 3: Baltimore, MD, to North Kingstown, RI
(16, September, 2014 — 07, October, 2014)

Contributors:
Brian Kennedy, Expedition Coordinator, NOAA Office of Ocean Exploration and Research (OER)
Kasey Cantwell, Operational Support, NOAA OER
Kimberly Galvez, Cherokee Nation Strategic Programs/NOAA OER
Scott France, Science Lead for Leg 3, University Corporation for Atmospheric Research (UCAR)/University of Louisiana at Lafayette
Susan Schnur, Science Lead for Leg 3, UCAR/Oregon State University
Meme Lobecker, Mapping Lead for Leg 2, ERT, Inc./NOAA OER
Linsday McKenna, Mapping Lead for Leg 3, ERT, Inc./NOAA OER
Catalina Martinez, NOAA OER
Jared Drewniak, Video Lead, ERT, Inc./NOAA OER
Brendan Reser, Data Manager, General Dynamics/NOAA OER
David Lovalvo, ROV Team Lead for Leg 2, ERT, Inc./NOAA OER
Todd Gregory, ROV Team Lead for Leg 3, ERT, Inc./NOAA OER

September 15, 2020

Office of Ocean Exploration and Research, NOAA
1315 East-West Hwy, SSMC3 RM 10210
Silver Spring, MD 20910

Abstract

The *Our Deepwater Backyard: Exploring Atlantic Canyons and Seamounts* expedition (EX-14-04 Legs 1-3) was a combined mapping and remotely operated vehicle (ROV) expedition to the canyons and seamounts of the Northwest Atlantic that took place between August 9 and October 7, 2014. Operations during this 46-day at sea expedition included a combination of ROV dives in support of NOAA Office of Ocean Exploration and Research (OER) and it's partner priorities as well as exploratory mapping operations targeting areas containing no or poor quality modern mapping data. During the expedition, Legs 2 and 3 focused on the U.S. Northeast Canyons, inter-canyons, and seamount areas while exploring six seamounts and nine canyons. During the expedition, 16 Deep Discoverer ROV dives were conducted from 376 m to 4689 m water depth for a total of 120 hours of bottom time, and surveyed using EM 302 multibeam sonar 15,161 square km over 26 days at sea. This report contains summaries of the operations, including mapping operations, outreach activities, and cruise schedule. All data associated with this expedition have been archived and are publicly available through the NOAA Archives.

This report can be cited as follows:

Kennedy, B., Cantwell, K., Galvez, K., France, S., Schnur, S., Lobecker, E., McKenna, L., Martinez, C., Drewniak, J., Reser, B., Lovalvo, D., and Gregory, T. (2014). Cruise Report: EX-14-04 Legs 2 & 3, Deepwater Backyard: Exploring Atlantic Canyons and Seamounts (ROV and Mapping). Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. OER Expedition Rep. 14-04. 38p. doi: https://doi.org/10.25923/cgd6-pq50

For further information, direct inquiries to:

NOAA Office of Ocean Exploration and Research
1315 East-West Hwy, SSMC3 RM 10210
Silver Spring, MD 20910
Phone: 301-734-1014
Email: oceanexplorer@noaa.gov

Table of Contents

1. Introduction	6
2. Expedition Overview	6
2.1 Rationale for Exploration	7
2.2 Objectives	7
3. Participants	8
4. Methodology	13
4.1 ROV Seafloor Surveys	13
4.2 Sampling Operations	14
4.3 Acoustic Operations	14
4.3.1 Multibeam Sonar (Kongsberg EM 302)	14
4.3.2 Sub-bottom Profiler (Knudsen Chirp 3260)	15
4.3.3 Split-beam Sonars (Simrad EK60)	15
4.3.4 Expendable Bathythermograph (XBT) Systems	15
4.4 Conductivity, Temperature, and Depth	16
4.5 Sun Photometer Measurements	16
5. Clearances and Permits	16
6. Schedule and Map	17
7. Results	20
7.1 ROV Survey Results	22
7.1.1 Accessing ROV Data	23
7.2 Sampling Operations Results	24
7.3 Acoustic Operations Results	24
7.3.1 Acoustic Operations Data Access	24
7.4 Conductivity, Temperature, and Depth Measurements	25

7.5 Sun Photometer Measurements 25
7.6 Engagement 26
8. Summary 26
8.1 Overview 26
8.2 Canyons 26
8.2.1 Geological Setting 26
8.2.2 Biological Setting 28
8.3 Seamounts 29
8.3.1 Geological Setting 29
8.3.2 Biological Setting 30
8.4 Other notable highlights 31
8.4.1 Partial taxon list of corals and fish (preliminary IDs requiring further analysis) 32
8.5 High-resolution Mapping Characterization 34
9. References 35
10. Appendix 37
10.1 Appendix A: Acronyms 37

Tables

Table 1: Onboard Mission Team Personnel 9

Table 2: Shore-based Operations Personnel 10

Table 3: Shore-based Science Participants 10

Table 4: Expedition Schedule 17

Table 5: Exploration Metrics 20

Table 6: Scientific Metrics 21

Table 7: Summary Dive Information 22

Figures

Figure 1. EX-14-04 Leg 2 Map 19

Figure 2. EX-14-04 Leg 3 Map 20

Figure 3. Dense population of Nantucket Canyon cup corals and brisingid sea stars 27

Figure 4. Coral diversity on Atlantis II Seamount Complex 29

Figure 5. Sepoke probe deployed on Gosnold Seamount 31

Figure 6. Side view of unnamed seamount explored during Dive 10 33

1. Introduction

By leading national efforts to explore the ocean and make ocean exploration more accessible, the NOAA Office of Ocean Exploration and Research (OER) is filling gaps in basic understanding of deep waters and the seafloor, providing deep-ocean data, information, and awareness. Exploration within the U.S. Exclusive Economic Zone (EEZ) and international waters, as part of Seabed 2030 efforts to produce a bathymetric map of the world ocean floor by 2030, supports key NOAA, national, and international goals to better understand and manage the ocean and its resources.

Using the latest tools and technology, OER explores unknown areas of the deep ocean. NOAA Ship *Okeanos Explorer* is one such tool. Working in close collaboration with government agencies, academic institutions, and other partners, OER conducts deep-sea exploration expeditions using advanced technologies on *Okeanos Explorer*, mapping and characterizing areas of the ocean that have not yet been explored. Collected data about deep waters and the seafloor — and the resources they hold — establishes a foundation of information and fills gaps in the unknown.

All data collected during *Okeanos Explorer* expeditions adhere to federal open-access data standards and are publicly available shortly after an expedition ends. This ensures the delivery of reliable scientific data needed to identify, understand, and manage key elements of the ocean environment.

Exploring, mapping, and characterizing the U.S. EEZ are necessary for a systematic and efficient approach to advancing the development of ocean resources, promoting the protection of the marine environment, and accelerating the economy, health, and security of our nation. As the only federal program solely dedicated to ocean exploration, OER is uniquely situated to lead partners in delivering critical deep-ocean information to managers, decision makers, scientists, and the public — leveraging federal investments to meet national priorities.

2. Expedition Overview

From 09, August, 2014, to 07, October, 2014, OER and partners conducted a three-part, telepresence-enabled ocean exploration expedition on *Okeanos Explorer* to collect critical baseline information and improve knowledge about unexplored and poorly understood deepwater areas offshore the Northeast U.S. The *Our Deepwater Backyard: Exploring Atlantic Canyons and Seamounts 2014* expedition (EX-14-04 Legs 1-3) focused primarily on the U.S.

Northeast Canyons and the New England Seamount Chain. Leg 2 operations focused on the submarine canyons along the U.S. continental margin that ran from Maine to North Carolina, and Leg 3 conducted operations in the U.S. Northeast Canyons and the New England Seamount Chain. Preceding expeditions in this region include the *Atlantic Canyons Undersea Mapping Expeditions (ACUMEN) 2012* (including NOAA Ships *Okeanos Explorer*, *Ferdinand Hassler, Nancy Foster,* and *Henry B. Bigelow*) as well as the *Northeast U.S. Canyons Expedition 2013*. As such, the *Our Deepwater Backyard* expedition was designed to provide timely, actionable information to support decision-making based on reliable and authoritative science. Like other OER expeditions, it also served as an opportunity to highlight the uniqueness and importance of the nation's deepwater environments. This report focuses on ROV operations conducted during EX-14-04 Leg 2 and Leg 3. For details about Mapping Operations conducted during these expeditions please refer to Lobecker and Candio (2020) and McKenna and Kennedy (2015).

2.1 Rationale for Exploration

The deepwater areas offshore the Northeastern U.S. continental margin are some of the least explored areas along the U.S. East Coast. Though this region is home to millions of Americans, very little is known about its offshore habitats.

As part of the planning for this expedition, NOAA collaborated with the scientific and management communities to assess the exploration needs and data gaps in unknown and poorly known areas of the Northeastern U.S. continental margin. To define the operating area for this expedition, NOAA considered the May 2011 NOAA Workshop on Systematic Telepresence-Enabled Exploration in the Atlantic Basin and priorities from resource managers.

Data and information from this expedition will help to improve our understanding of the deep-ocean habitats of the U.S. continental margin and the connections between communities throughout the Atlantic Basin. It will also inform deep-sea management plans for habitat areas of particular concern (HAPCs), marine protected areas (MPAs), and national marine sanctuaries; support local scientists and managers seeking to understand and manage deep-sea resources; and stimulate subsequent exploration, research, and management activities.

2.2 Objectives

The expedition addressed scientific themes and priority areas put forward by NOAA scientists and resource managers, the Ocean Exploration Advisory Working Group (OEAWG) workshop results (Atlantic Basin Workshop, 2011), NOAA National Marine Fisheries Service (NMFS), NOAA Office of National Marine Sanctuaries (ONMS), Northeast Regional Ocean Council (NROC), Mid-Atlantic Regional Council on the Ocean (MARCO), and the broad ocean science community. The primary objective of the expedition was to survey deepwater areas of the Northeast U.S. submarine canyons and New England Seamount Chain. Specifically, this expedition sought to:

- Collect high-resolution bathymetry in areas with no or low-quality mapping data.
- Acquire a foundation of remotely operated vehicle (ROV), sonar, and oceanographic data to better understand the characteristics of the water column and fauna that live there.
- Identify, map, and explore the diversity and distribution of benthic habitats, including fish habitats, deep-sea coral and sponge communities, chemosynthetic communities, and biological communities.
- Engage a broad spectrum of the scientific community and the public in telepresence-based ocean exploration.
- Provide a foundation of publicly accessible data and information products to spur further exploration, research, and management activities.

3. Participants

EX-14-04 Legs 2 & 3 included onboard mission personnel as well as shore-based operations and science personnel who participated remotely via telepresence technology. See **Tables 1**, **2**, and **3** for lists of onboard and shore-based personnel who supported EX-14-04 Legs 2 & 3.

Table 1. EX-14-04 Legs 2 & 3 onboard mission team personnel.

Name (First, Last)	Title	Affiliation
Leg 2		
Brian Kennedy	Expedition coordinator	NOAA OER
Jamie Austin	Science lead	University of Texas Institute for Geophysics
Jesse Ausubel	Science lead	Rockefeller University
Elizabeth “Meme” Lobecker	Mapping lead	NOAA OER (ERT, Inc.)
Jared Drewniak	Video lead	NOAA OER (ERT, Inc.)
Brendan Reser	Data lead	NOAA National Coastal Data Development Center (NCDDC) General Dynamic Information Technology (GDIT)
David Lovalvo	ROV Team lead	NOAA OER (ERT, Inc.)
Dave Wright	ROV Engineering team	UCAR
Bobby Mohr	ROV Engineering team	UCAR
Jeffery Lanning	ROV Engineering team	UCAR

Karl McLetchie	ROV Engineering team	UCAR
Todd Gregory	ROV Engineering team	UCAR
Joshua Carlson	ROV Engineering team	UCAR
Sean Kennison	ROV Engineering team	UCAR
Brian Bingham	ROV Engineering team	UCAR
Roland Brian	Video Engineer	UCAR
Art Howard	Video Editor	UCAR
Eric Schwaab	Guest	The National Aquarium
Jay O'Dell	Guest	The Nature Company
Aaron Kornbluth	Guest	The Pew Charitable Trusts
Cameron Hume	Guest	Foreign Service (ret.)
Kiley Dancy	Guest	NMFS
Craig Russell	Guest	NMFS
Mike Clark	Guest	Office of Management and Budget (OMB)
Kim Miller	Guest	OMB
Michael Phelps	Guest	Department of Commerce (DOC)
John Garneski	Guest	DOC
Walter Cruickshank	Guest	Bureau of Ocean Energy Management (BOEM)
John McDonough	Guest	NOAA OER
Leg 3		
Brian Kennedy	Expedition coordinator	NOAA OER
Scott France	Science lead	University of Louisiana at Lafayette (ULL)
Susan Schnur	Science lead	Oregon State University (OSU)
Linsday McKenna	Mapping lead	NOAA OER (ERT, Inc.)
Jared Drewniak	Video lead	NOAA OER (ERT, Inc.)
Brendan Reser	Data lead	NOAA NCDDC (GDIT)
Todd Gregory	ROV Team lead	NOAA OER (ERT, Inc.)
Dave Wright	ROV Engineering team	UCAR
Bobby Mohr	ROV Engineering team	UCAR
Jeff Williams	ROV Engineering team	UCAR
Karl McLetchie	ROV Engineering team	UCAR
Dan Rogers	ROV Engineering team	UCAR

Joshua Carlson	ROV Engineering team	UCAR
Chris Ritter	ROV Engineering team	UCAR
Jeffery Lanning	ROV Engineering team	UCAR
James Miller	ROV Engineering team	UCAR
Roland Brian	Video Engineer	UCAR
Art Howard	Video Engineer	UCAR

Table 2. EX-14-04 Legs 2 & 3 shore-based operations personnel.

Name (First, Last)	Affiliation	Position
Catalina Martinez	NOAA OER	RI Regional Manager
Kelley Elliot	NOAA OER	Shore-side operations coordinator
Kasey Cantwell	NOAA OER	Web coordinator and shore-side operations coordinator
Dwight Coleman	University of Rhode Island (URI) Inner Space Center (ISC)	ISC Director
Kerry Whalen	URI ISC	ISC Video Engineer
Steve Damas	UCAR	ISC Video Engineer
Bob Knott	URI ISC/Ocean Exploration Trust (OET)	ISC Video Engineer
Derek Sutcliffe	URI ISC	ISC IT staff
Dave Lapage	URI ISC/OET	ISC Video Engineer

Table 3. EX-14-04 Legs 2 & 3 shore-based science participants.

Name (First, Last)	Email	Affiliation
Peter Auster	peter.auster@uconn.edu	University of Connecticut (UConn)/ Science and Research Fund (SRF)
Steve Auscavitch	steven.auscavitch@maine.edu	University of Maine
James Austin	jamie@utig.ig.utexas.edu	University of Texas at Austin/Jackson School of Geosciences
Jesse Ausubel	ausubel@mail.rockefeller.edu	Rockefeller University
Amy Baco-Taylor	abacotaylor@fsu.edu	Florida State University (FSU)
Bernie Ball	bernie.ball@duke.edu	Duke University Marine Lab
Kimberly Barber	kbarber@midatlanticocean.org	MARCO
Neah Baechler	baechlernv@g.cofc.edu	College of Charleston
Ewann Berntson	ewann.berntson@noaa.gov	NOAA NMFS
Margot Bohan	margot.bohan@noaa.gov	NOAA OER

Ellie Bors	ekbors@gmail.com	Woods Hole Oceanographic Institution (WHOI)
Adam Boyette	adam.boyette@noaa.gov	NOAA NCDDC
Sandra Brooke	sbrooke@fsu.edu	FSU Coastal Marine Laboratory (CML)
Robert Carney	rcarne1@lsu.edu	Louisiana State University (LSU)
Jason Chaytor	jchaytor@usgs.gov	U.S. Geological Survey (USGS)
Rachel Clostio	rclostio@louisiana.edu	ULL
Erik Cordes	ecordes@temple.edu	Temple University
Katharine Coykendall	dcoykendall@usgs.gov	USGS
Wilmelie Cruz	wilmelie@hotmail.com	University of Maryland Eastern Shore (UMES)
Kiley Dancey	kdancey@mafmc.org	MARCO
Amanda Demopoulos	ademopoulos@usgs.gov	USGS
Emily Duwan	emilyduwan@gmail.com	UConn
Jack Evans	john.evans@noaa.gov	NOAA OER
Stephanie Farrington	sfarrington@fau.edu	Florida Atlantic University (FAU) - Harbor Branch Oceanographic Institute (HBOI)
Michael Ford	michael.ford@noaa.gov	NOAA NMFS
Scott France	france@louisiana.edu	ULL
Lisa Gilbert	lgilbert@williams.edu	Williams College
Sarah Graddy	sarah.graddy@noaa.gov	NOAA OER
Tara Harmer Luke	luket@stockton.edu	The Richard Stockton College of New Jersey
Rebecca Helm	rebecca.rae.helm@gmail.com	Brown University
Arlo Hemphill	ahemphill@midatlanticocean.org	MARCO
Santiago Herrera	tiagohe@gmail.com	WHOI
Jeffrey Herter	jeff.herter@dos.ny.gov	New York State Department of State, Office of Planning & Development
Taylor Heyl	theyl@whoi.edu	WHOI
Veerle Huvenne	vaih@noc.ac.uk	National Oceanography Centre (NOC)
Brian Jordan	brian.jordan@boem.gov	BOEM
Brian Kinlan	brian.kinlan@noaa.gov	NOAA/National Ocean Service (NOS)/National Centers for Coastal Ocean Science (NCCOS) Biogeography Branch
Astrid Leitner	aleitner@hawaii.edu	University of Hawaiʻi at Mānoa (UH)
Christopher Mah	brisinga@gmail.com	Invertebrate Zoology, USNM, Smithsonian

Larry Maye	larry@ccom.unh.edu	University of New Hampshire (UNH) Center for Coastal and Ocean Mapping (CCOM)
Laura McKay	laura.mckay@deq.virginia.gov	VA Coastal Zone Management (CZM)/ & MARCO
Lindsay McKenna	lindsay.mckenna@noaa.gov	NOAA OER
Chuck Messing	messingc@nova.edu	NSU
James Moore	james.moore@boem.gov	BOEM
Nicole Morgan	nbmorgan11@gmail.com	FSU
Cheryl Morrison	cmorrison@usgs.gov	USGS
Katie Musser	katie.musser@mail.wlc.edu	ULL
Martha Nizinski	nizinski@si.edu	NOAA NMFS
Kris Ohleth	kohleth@midatlanticocean.org	MARCO
Jay Odell	jodell@tnc.org	The Nature Conservancy
Shirley Pomponi	spomponi@fau.edu	FAU - HBOI/FAU Cooperative Institute for Ocean Exploration, Research, & Technology (CIOERT)
Andrea Quattrini	andrea.quattrini@temple.edu	USGS
John Reed	jreed12@hboi.fau.edu	HBOI
Thomas Ritter	thomas.ritter@msu.montana.edu	Montana State University
Estefania Rodriguez	erodriguez@amnh.org	American Museum of Natural History
Brendan Roark	broark@geos.tamu.edu	Texas A&M University
Steve Ross	rosss@uncw.edu	University of North Carolina (UNC) at Wilmington
Carolyn Ruppel	cruppel@usgs.gov	USGS
Esprit Saucier	heestand.saucier@louisiana.edu	ULL
John Schiff	jschiff@tamu.edu	Texas A&M University
Susan Schnur	sschnur@coas.oregonstate.edu	OSU
Tim Shank	tshank@whoi.edu	WHOI
Liz Shea	eshea@delmnh.org	Delaware Museum of Natural History
Randy Singer	randal.a.singer@as.ua.edu	University of Alabama Ichthyology Collection
Adam Skarke	adam.skarke@msstate.edu	Mississippi State University
Brad Stevens	bgstevens@umes.edu	UMES
Alice Stratton	alice.stratton@noaa.gov	NOAA/NOS/ONMS/Stellwagen Bank National Marine Sanctuary (SBNMS)

Michelle Taylor	michelle.taylor@zoo.ox.ac.uk	University of Oxford
Paul Ticco	paul.ticco@noaa.gov	NOAA/ONMS
Michael Vecchione	vecchiom@si.edu	NOAA NMFS Systematics Lab
Josh Voss	Jvoss2@fau.edu	FAU - HBOI
Les Watling	watling@hawaii.edu	UH
Scott White	swhite@geol.sc.edu	University of South Carolina
Rhian Waller	rhian.waller@maine.edu	University of Maine
Jann Wendt	jwendt@ecology.uni-kiel.de	University of Kiel
Gary Williams	gwilliams@calacademy.org	California Academy of Sciences

4. Methodology

To accomplish its objectives, EX-14-04 Legs 2 & 3 used:

- Dual-bodied ROV system (ROVs *Deep Discoverer* and *Seirios*) to conduct daytime seafloor and water column surveys to help further characterize the deepwater fauna and geology of the region.
- Sonar systems (Kongsberg EM 302 multibeam sonar, Knudsen 3260 sub-bottom profiler, and Simrad EK60 split-beam sonars) to conduct mapping operations at night and when the ROVs were on deck.
- A high-bandwidth satellite connection to provide real-time ship-to-shore communications (telepresence).

All environmental data collected by NOAA are covered by a data management plan (Kennedy, 2014) to ensure they are archived and publicly accessible (see Section 7.1.1).

4.1 ROV Seafloor Surveys

ROV dive operations supported the expedition objectives listed in Section 2.2 and included high-resolution visual surveys of seafloor and water column habitat. During each dive, the ROVs descended to the seafloor and then moved from waypoint to waypoint, documenting the geology and biology of the area. Each ROV dive was approximately 6-10 hours long, conditions and logistics permitting. Dives were primarily conducted during the day (operations described in detail by Quattrini et al., 2015 and Kennedy et al., 2019). Additional information about the general process of site selection, collaborative dive planning, scientific equipment on the ROVs, and the approach to benthic exploration used on *Okeanos Explorer* can be found in Kennedy et al. (2019).

Onboard and shore-based scientists identified each encountered organism to the lowest taxon possible, based on data available during real-time assessment. Additionally, they provided geological interpretations of the observed substrate throughout each ROV seafloor survey.

For water column exploration, a series of transects were performed during vehicle ascent following the completion of the benthic/seafloor exploration. Transects primarily targeted the deep scattering layer and the waters directly above and below it. Specific transect depths were decided each day during ROV descent through an evaluation of the Simrad EK60 data; ROV conductivity, temperature, and depth (CTD) data; and the acoustically-determined position of the deep scattering layer. Additionally, when seafloor depth allowed, a standard set of deeper transects were also completed at 100 m depth intervals, between 1,200-800 meters depth, with 10 minutes of transect time at each interval. Specific transect depths and times are noted in each dive summary (see Section 7.1.1).

4.2 Sampling Operations

No samples were taken during EX-14-04.

4.3 Acoustic Operations

Acoustic operations included Kongsberg EM 302 multibeam, Simrad EK60 split-beam, and Knudsen sub-bottom profiler data collection (Loebecker and Candio, 2020; McKenna and Kennedy, 2015). The schedule of mapping operations included overnight transits and whenever the ROVs were on deck. Lines were planned to maximize edge matching of existing data or filling of data gaps in areas with incomplete bathymetry coverage. In regions with no existing data, exploration transit lines were planned to optimize potential discoveries. Targeted mapping operations were conducted in the vicinity of the (1) Northeast continental margin and (2) New England Seamount Chain.

4.3.1 Multibeam Sonar (Kongsberg EM 302)

Multibeam seafloor mapping data were collected using the Kongsberg EM 302 sonar, which operates at a frequency of 30 kilohertz (kHz). Multibeam mapping operations were conducted during all overnight transits between ROV dive sites. Multibeam data quality was monitored in real time by acquisition watchstanders. Ship speed was adjusted to maintain data quality as necessary.

Whenever possible, transits were designed to maximize coverage over seafloor areas with no previous high-resolution mapping data. In these focus areas, line spacing was generally planned to ensure 30% overlap between lines at all times. Cutoff angles in the Seafloor Information System (SIS) software were generally adjusted on both the port and starboard sides to ensure the best balance between data quality and coverage. Overnight surveys were also completed in areas that were previously mapped with a lower-resolution multibeam sonar system.

Additionally, multibeam mapping operations were conducted directly over planned ROV dive sites to collect seafloor mapping data to help refine dive plans. These operations collected data about seafloor depth (bathymetry), seafloor acoustic reflectivity (seafloor backscatter), and water column reflectivity (water column backscatter).

Background data used to guide exploratory multibeam mapping operations included the 2012 ACUMEN cruises and three *Okeanos Explorer* cruises (EX-13-03, EX-13-04 Legs 1 & 2), since they gathered baseline information on deepwater canyons off the Northeastern U.S. seaboard, mapping along the continental shelf and slope from North Carolina to the northeastern boundary of the U.S. EEZ. Some dive planning and mapping operations were conducted using bathymetric grids created using all available bathymetry archived at NOAA's National Centers for Environmental Information (NCEI) and their Autogrid tool. Sandwell and Smith satellite altimetry data were also used to plan operations (Sandwell et al., 2014).

4.3.2 Sub-bottom Profiler (Knudsen Chirp 3260)

The primary purpose of the Knudsen Chirp 3260 (3.5 kHz) sonar is to image sediment layers underneath the seafloor to a maximum depth of about 80 m below the seafloor, depending on the specific sound velocity of the substrate. The sub-bottom profiler was operated simultaneously with the multibeam sonar during mapping operations to provide supplemental information about the sedimentary features underlying the seafloor.

4.3.3 Split-beam Sonars (Simrad EK60)

At the time of this expedition, *Okeanos Explorer* was equipped with split-beam transducers (Simrad EK60 general purpose transceivers, 18 kHz). This sonar was used continuously throughout EX-14-04 Legs 2 & 3 during both overnight mapping operations and daytime ROV operations. The sonars provided calibrated target strength measurements of water column features such as dense biological layers and schools of fish. These sonars also helped detect gaseous seeps on the seafloor. EK60 data were also used during midwater transects of ROV dives to detect the depth of the deep scattering layers, which are aggregations of biological organisms in the water column.

4.3.4 Expendable Bathythermograph (XBT) Systems

The Lockheed Martin Sippican Deep Blue expendable bathythermographs (XBTs) were collected every six hours and applied in real time using SIS. Sound speed at the sonar head was determined using sound speed from a flow-through thermosalinograph (TSG).

4.4 Conductivity, Temperature, and Depth

CTD measurements were collected by two different methods. The most frequent method was with the integrated ROV CTD system. This system records CTD and associated sensors on every dive. The second method was with a dedicated CTD lowered with a winch to provide better information of the critical properties of the water column. Additional sensors installed on both of the CTDs include measured light scattering spectroscopy (LSS), dissolved oxygen (DO), and oxygen reduction potential (ORP).

4.5 Sun Photometer Measurements

OER gathers limited at-sea measurements aboard *Okeanos Explorer* to support a NASA-led, long-term research effort that assesses marine aerosols. As time allowed on cloud-free days, onboard personnel collected georeferenced sun photometer measurements for the Maritime Aerosol Network (MAN) component of the Aerosol Robotic Network (AERONET). AERONET is a network of sun photometers that measure atmospheric aerosol properties around the world (Kennedy, 2014). MAN complements AERONET by conducting sun photometer measurements on ships of opportunity to monitor aerosol properties over the global ocean.

5. Clearances and Permits

Pursuant to the National Environmental Policy Act (NEPA), OER is required to include in its planning and decision-making processes appropriate and careful consideration of the potential environmental consequences of actions it proposes to fund, authorize, and/or conduct. The Companion Manual for NOAA Administrative Order 216-6A describes the agency's specific procedures for NEPA compliance.

An environmental review memorandum was completed for all *Okeanos Explorer* expeditions in 2020 in accordance with Section 4 of the companion manual in the form of a categorical exclusion worksheet (Kennedy, 2014). Based on this review, a categorical exclusion was determined to be the appropriate level of NEPA analysis necessary, as no extraordinary circumstances existed that required the preparation of an environmental assessment or environmental impact statement.

The expedition was conducted prior to the establishment of the Northeast Canyons and Seamounts Marine National Monument off the Northeast U.S. coast. The expedition did not involve any other Monuments or Sanctuaries in the vicinity. No samples were collected during the *Our Deepwater Backyard: Exploring Atlantic Canyons and Seamounts 2014* expedition (EX-14-04 Legs 1-3).

6. Schedule and Map

EX-14-04 Legs 2 & 3 were conducted over a total of 26 days at sea, from September 04, 2014, to October 07, 2014. The cruises departed from North Kingstown, RI, and returned to port in North Kingstown, RI. See **Table 4** for a day-by-day breakdown of EX-14-04 Legs 2 & 3. There were 23 scheduled dives, with 16 dives achieved (see **Table 7** for details), although Dive 06 was aborted during descent. Due to weather and currents, some dives were canceled. See **Figure 1** for a map of EX-14-04 Leg 2, and **Figure 2** for the track, dive sites, and bathymetry collected during EX-14-04 Leg 3.

Table 4. EX-14-04 Legs 2 & 3 schedule

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
08/31	**09/01**	**09/02**	**09/03** Mobilization at North Kingstown, RI	**09/04** EX Departure for Leg 2 Overnight mapping operations	**09/05** Dive 01: Shakedown dive Lindenkohl Canyon Overnight mapping operations	**09/06** Dive 02: Washington Canyon Overnight mapping operations
09/07 Dive 03: Norfolk Canyon Overnight mapping operations	**09/08** Dive canceled Transit mapping	**09/09** Transit	**09/10** Transit to Baltimore, MD Star Spangled Spectacular in Baltimore Harbor	**09/11** Star Spangled Spectacular in Baltimore Harbor	**09/12** Star Spangled Spectacular in Baltimore Harbor *Okeanos Explorer* Ship Tours and Pier Side Outreach	**09/13** Star Spangled Spectacular in Baltimore Harbor *Okeanos Explorer* Ship Tours and Pier Side Outreach

09/14 Star Spangled Spectacular in Baltimore Harbor *Okeanos Explorer* Ship Tours and Pier Side Outreach	**09/15** Star Spangled Spectacular in Baltimore Harbor *Okeanos Explorer* Ship Tours and Pier Side Outreach	**09/16** EX Departure	**09/17** Transit to MOC-A	**09/18** EX Departure for Leg 3	**09/19** Dive 01: Phoenix Canyon Overnight mapping operations	**09/20** Dive 02: Hendrickson Canyon Overnight mapping operations
09/21 Dive 03: McMaster Canyon Overnight mapping operations	**09/22** Dive canceled Transit mapping	**09/23** Dive 04: East of Veatch (Okeanos Canyon) Overnight mapping operations Live Interaction with HBOI	**09/24** Dive canceled Transit mapping	**09/25** Dive 05: Retriever Seamount West Slope Overnight mapping operations	**09/26** Dive 06: Asterias Seamount (Aborted) Overnight mapping operations	**09/27** Dive 07: Atlantis II North West Slope Overnight mapping operations
09/28 Dive 08: Gosnold Seamount Overnight mapping operations	**09/29** Dive 09: Kelvin Seamount Overnight mapping operations	**09/30** Dive 10: Unnamed Deep Seamount Overnight mapping operations Live Interaction with INCISE	**10/01** Dive 11: Physalia Seamount Overnight mapping operations	**10/02** Dive canceled Overnight mapping operations	**10/03** Dive canceled Overnight mapping operations	**10/04** Dive 12: Ryan Canyon Overnight mapping operations
10/05 Dive canceled Overnight mapping operations	**10/06** Dive 13: Nantucket Canyon Overnight mapping operations	**10/07** Arrival: North Kingstown, RI	**10/08**	**10/09**	**10/10**	**10/11**

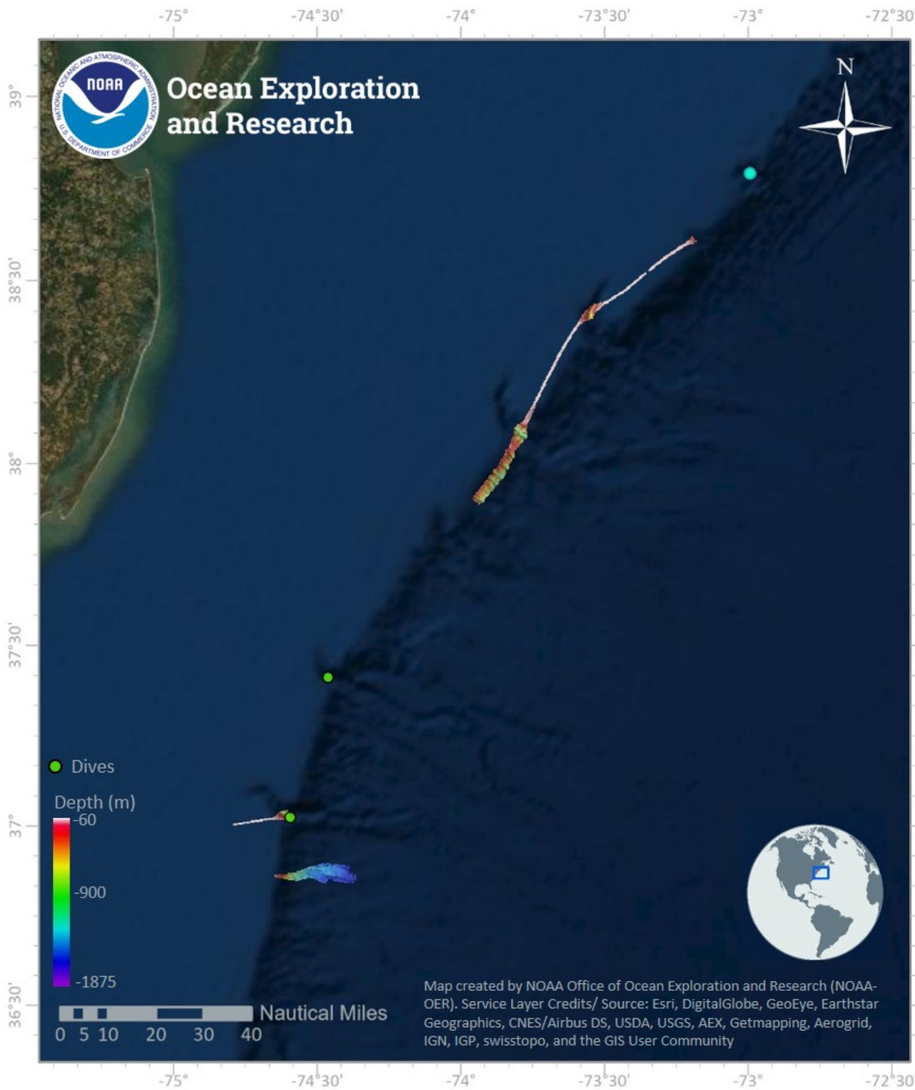

Figure 1. Map showing the bathymetry data collected and dive sites (green circles) during EX-14-04 Leg 2.

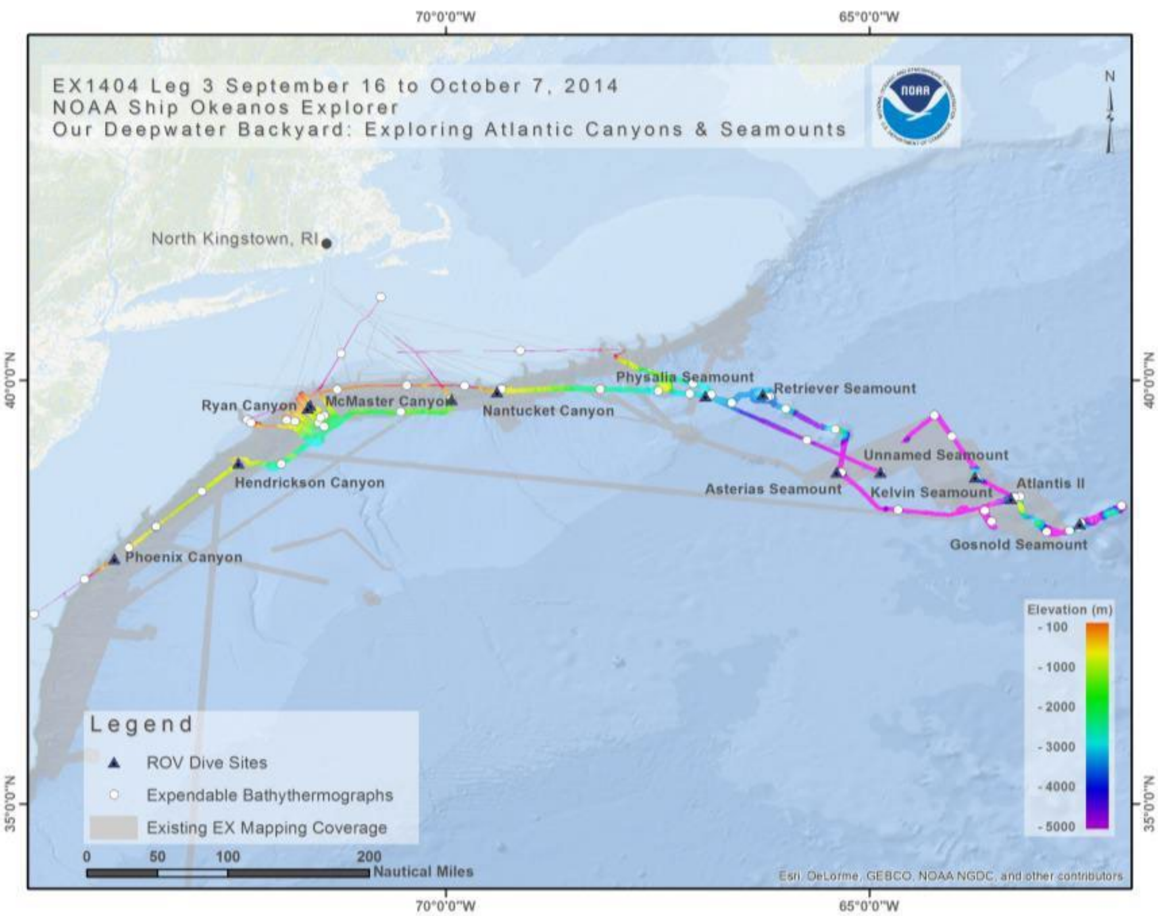

Figure 2. Map showing bathymetry data collected and key operational areas during EX-14-04 Leg 3.

7. Results[1]

EX-14-04 Legs 2 and 3 completed 16 ROV dives over 28 days at sea, collecting over 82 hours of high-resolution video footage of the canyons and seamounts. Metrics for the major exploration and scientific accomplishments during EX-14-04 Legs 2 & Leg 3 are summarized in **Tables 5** and **6**. More detailed results are presented in the subsections that follow.

Table 5. Summary of exploration metrics for EX-14-04 Legs 2 & 3

Exploration Metrics	Totals
Leg 2	
Days at sea	7
Linear km mapped by EM 302	172

[1] If you are unable to access the results noted here, contact ex.expeditioncoordinator@noaa.gov.

Square km covered by EM 302	280
Square km covered by EM 302 in U.S. EEZ	222
Vessel CTD casts	0
XBT casts	5
ROV dives	3
ROV dives in U.S. EEZ	3
Maximum ROV seafloor depth (m)	676
Minimum ROV seafloor depth (m)	376
Total time on bottom (hh:mm:ss)	18:59:23
Water column survey time (hh:mm:ss)	0:00:00
Total ROV time (hh:mm:ss)	23:21:57
Leg 3	
Days at sea	19
Linear km mapped by EM 302	3,805
Square km covered by EM 302	14,881
Square km covered by EM 302 in U.S. EEZ	9,042
Vessel CTD casts	0
XBT casts	55
ROV dives	13
ROV dives in U.S. EEZ	8
Maximum ROV seafloor depth (m)	4,689
Minimum ROV seafloor depth (m)	998
Total time on bottom (hh:mm:ss)	63:47:00
Water column survey time (hh:mm:ss)	0:40:00
Total ROV time (hh:mm:ss)	96:58:48

Table 6. Summary of scientific metrics for EX-14-04 Legs 2 & 3. Rows 1-4 are also included in the following ROV Dive Summary **Table 7** as Sci. Met. 1-4.

Scientific Metrics	Totals
1) Dives during which living corals and sponges were observed	14
2) Dives during which chemosynthetic communities were observed	0
3) Dives during which active seeps/vents were observed	0
4) Dives during which diverse benthic communities were observed	15

Total samples	0
Actively participating scientists, students, and resource managers	57

7.1 ROV Survey Results

Depth ranges explored during the three ROV surveys for EX-14-04 Leg 2 were between 376 and 676 meters and for the 13 ROV surveys for EX-14-04 Leg 3 were between 998 and 4,689 meters. During the three dives for EX-14-04 Leg 2, the ROVs spent a total of approximately 19 hours on the bottom, while over the 13 dives during EX-14-04 Leg 3, the ROVs spent a total of approximately 64 hours on the bottom and 40 minutes conducting water column exploration (see **Table 6** for more cumulative results). See **Table 7** for dive-specific information for each of the dives.

Table 7. Summary information for the 16 ROV dives conducted during EX-14-04 Legs 2 & 3. **Table 6** "Scientific Metrics" contains the definitions for Sci. Met. 1-4.

Date (yyyy mmdd)	Dive #	Site Name	On Bottom Latitude (dd)	On Bottom Longitude (dd)	Max Depth (m)	Dive Duration (hh:mm:ss)	Bottom Time (hh:mm:ss)	Water Column Exploration Time (hh:mm:ss)	Sci. Met. 1	Sci. Met. 2	Sci. Met. 3	Sci. Met. 4
Leg 2												
20140905	1	Lindenkohl Canyon	38.79365	72.9925333	669.5	08:58:20	07:49:31	00:00:00	No	No	No	Yes
20140906	2	Washington Canyon	37.4101833	74.46455	643.7	07:39:40	05:56:53	00:00:00	Yes	No	No	Yes
20140907	3	Norfolk Canyon	37.0280167	74.5985167	675.9	06:44:51	05:12:59	00:00:00	Yes	No	No	Yes
Leg 3												
20140919	1	Phoenix Canyon	37.8911333	73.9123333	1172.3	08:01:42	06:13:06	00:00:00	Yes	No	No	Yes
20140920	2	Hendrickson Canyon	39.0234833	72.4484333	1669.0	08:08:27	06:08:21	00:00:00	Yes	No	No	Yes
20140921	3	McMaster Canyon	39.7069	71.5985667	1358.2	08:18:50	06:05:29	00:00:00	Yes	No	No	Yes

20140923	4	East of Veatch (Okeanos Canyon)	39.85985	69.3940333	1517.1	08:07:53	05:37:49	00:00:00	Yes	No	No	Yes
20140925	5	Retriever Seamount West Slope	39.83605	66.2522333	2142.2	08:14:44	05:52:28	00:00:00	Yes	No	No	Yes
20140926	6	Asterias Seamount (Aborted)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
20140927	7	Atlantis II North West Slope	38.603	63.3225167	2746.9	11:10:50	08:09:52	00:00:00	Yes	No	No	Yes
20140928	8	Gosnold Seamount	38.3023833	62.5107167	2138.4	07:31:10	05:24:42	00:00:00	Yes	No	No	Yes
20140929	9	Kelvin Seamount	38.8575333	63.74865	2075.6	06:44:55	04:27:26	00:00:00	Yes	No	No	Yes
20140930	10	Unnamed Deep Seamount	38.91415	64.86675	4689.0	08:48:10	03:26:12	00:00:00	Yes	No	No	Yes
20141001	11	Physalia Seamount	39.81085	66.9320333	2588.5	07:11:02	04:04:47	00:00:00	Yes	No	No	Yes
20141004	12	Ryan Canyon	39.6686	71.6296333	1524.4	05:25:41	03:38:12	00:00:00	Yes	No	No	Yes
20141006	13	Nantucket Canyon	39.7729167	69.9294167	1880.8	09:15:24	04:38:36	00:40:00	Yes	No	No	Yes

7.1.1 Accessing ROV Data

OER Digital Atlas

ROV data from EX-14-04 Legs 2 & 3 are archived at NCEI and available through OER's Digital Atlas (https://www.ncei.noaa.gov/maps/oer-digital-atlas/mapsOE.htm).

To access these data, click on the Search tab, for ROV data pertaining to EX-14-04 Leg 2 enter "EX1404L2" in the Enter Search Text field, and click Search. Click on the point that represents EX-14-04 Leg 2 to access data options. In the pop-up window, select the ROV Data Access tab for links to the ROV dive data, which is organized by dive.

For ROV data pertaining to EX-14-04 Leg 3 enter "EX1404L3" in the Enter Search Text field, and click Search. Click on the point that represents EX-14-04 Leg 3 to access data options. In the pop-up window, select the ROV Data Access tab for links to the ROV dive data, which is organized by dive.

ROV Dive Summaries

Individual ROV dive summaries for EX-14-04 Leg 2 and associated ROV dive data are archived at NCEI and available on their *Okeanos Explorer* website (https://accession.nodc.noaa.gov/0183225).

Individual ROV dive summaries for EX-14-04 Leg 3 and associated ROV dive data are archived at NCEI and available on their *Okeanos Explorer* website (https://doi.org/10.25921/4jb1-rq88).[2]

ROV Dive Video

To search, preview, and download the dive video for *Okeanos Explorer*, go to the OER Video Portal (https://www.nodc.noaa.gov/oer/video/).

7.2 Sampling Operations Results

No samples were collected during EX-14-04 Legs 2-3.

7.3 Acoustic Operations Results

During EX-14-04 Legs 2 & 3, multibeam mapping operations results included 3,977 linear kilometers (km) mapped and 15,161 km^2 covered (9,264 km^2 of these in the U.S. EEZ). Additional information about the mapping conducted during EX-14-04 Leg 2 & 3, including data quality assessments, are in the EX-14-04 Leg 2 mapping data report (Loebecker and Candio, 2020) and the EX-14-04 Leg 3 mapping data report (McKenna and Kennedy, 2015).

7.3.1 Acoustic Operations Data Access

Multibeam Sonar (Kongsberg EM 302)

The multibeam dataset for the expedition is archived at NCEI and is accessible through their Bathymetric Data Viewer (https://maps.ngdc.noaa.gov/viewers/bathymetry/). To access these data, click on the Search Bathymetric Surveys button, select “NOAA Ship Okeanos Explorer” from the Platform Name dropdown menu, and “EX1404L2” from the Survey ID dropdown menu for EX-14-04 Leg 2 and/or “EX1404L3” from the Survey ID dropdown menu for EX-14-04 Leg 3. Click OK, and the ship track for the cruise will appear on the map. Click the ship track for options to download data.

Sub-bottom Profiler (Knudsen Chirp 3260)

[2] ROV dive summaries are typically available 90 days after an ROV cruise. For access in the interim, contact ex.expeditioncoordinator@noaa.gov.

The sub-bottom profiler was not run during any of the ROV dive operations during EX-14-04 Legs 2 & 3, but generally was operated during multibeam mapping operations. These data are archived at NCEI and accessible through their Trackline Geophysical Data Viewer (https://maps.ngdc.noaa.gov/viewers/geophysics/). To access these data, select "Subbottom Profile" under Marine Surveys and click on Search Marine Surveys. In the pop-up window, select "EX1404_2" for EX-14-04 Leg 2 or "EX1404_3" for EX-14-04 Leg 3 in the Filter by Survey IDs dropdown menu. Click OK, and the ship track for the cruise will appear on the map. Click the ship track for options to download data.

Split-beam Sonars (Simrad EK60)

EK60 water column data for EX-14-04 are archived at NCEI and available through their Water Column Sonar Data Viewer (https://www.ngdc.noaa.gov/maps/water_column_sonar/index.html). To access these data, click on the Additional Filters button, deselect "All" next to Survey ID, and select "EX1404L2" for EX-14-04 Leg 2 or "EX1404L3" for EX-14-04 Leg 3 from the Survey ID list. Click OK, and the ship track for the cruise will appear on the map. Click on the ship track for options to download data.

7.4 Conductivity, Temperature, and Depth Measurements

CTD profile data from EX-14-04 are archived at NCEI and available through OER's Digital Atlas (https://www.ncei.noaa.gov/maps/oer-digital-atlas/mapsOE.htm). To access these data, click on the Search tab, enter "EX1404L2" for EX-14-04 Leg 2 or "EX1404L3" for EX-14-04 Leg 3 in the Enter Search Text field, and click Search. Click on the point that represents EX-14-04 Leg 2 or EX-14-04 Leg 3 to access data options. In the pop-up window, select the Data Access tab for a link to download the CTD profile data.

ROV CTD data can be found with the dive summary data pages. For data from EX-14-04 Leg 2, use link: https://accession.nodc.noaa.gov/0183225. For data from EX-14-04 Leg 3, use link: https://doi.org/10.25921/4jb1-rq88.

7.5 Sun Photometer Measurements

Sun photometer measurements are available through NASA's MAN component of AERONET (https://aeronet.gsfc.nasa.gov/new_web/maritime_aerosol_network.html). Access these data by searching the table for "2014," "Okeanos Explorer," and "Northwest Atlantic." Click on the links to download the data. (Note: There may be more than one entry for *Okeanos Explorer* in a region in a given year.)

7.6 Engagement

The *Our Deepwater Backyard: Exploring Atlantic Canyons and Seamounts 2014* expedition engaged with audiences around the world, opening a window of understanding into the deep sea. Highlights are listed below:

- During EX-14-04, live interactions and ship tours with over 2,000 visitors for the Star Spangled Spectacular (Baltimore, MD) event were conducted to engage a diversity of audiences that included extensive media coverage and VIP Tours. This coverage amplified the impact of the expedition, increasing the audience reached (https://oceanexplorer.noaa.gov/annual-report-2014/noaa-and-marylands-star-spangled-spectacular.html).

8. Summary

8.1 Overview

From September 4 to October 7, 2014, the NOAA Ship *Okeanos Explorer* and ROV *Deep Discoverer* (D2) explored deep canyons and seamounts off the Northeast U.S. on Legs 2 & 3 of the *Our Deepwater Backyard: Exploring Atlantic Canyons and Seamounts 2014* expedition. D2 completed 16 dives to depths ranging from 376 to 4,693 m at sites along the continental slope of the Northeast U.S. and offshore along the New England Seamount Chain; an additional six planned dives had to be cancelled due to weather or sea state conditions. Six ROV dives were conducted in canyons cutting into the continental slope, one each in Lindenkohl, Washington, Norfolk, Phoenix, Hendrickson, McMaster, Ryan, and Nantucket Canyons, and an unnamed minor canyon east of Veatch Canyon; seven dives were conducted on offshore seamounts, including Retriever and Physalia in the U.S. EEZ, and Atlantis II, Gosnold, Kelvin, Asterias (this dive was aborted at approximately 2,200 meters, before the D2 reached bottom, due to deteriorating weather conditions), and a deep unnamed star-shaped seamount east of Asterias Seamount. The latter was D2's deepest dive to date. In the offshore region, in some cases, weather and the strength of the Gulf Stream current required that, in some cases, primary dive targets be moved from one seamount to an alternate location. Nonetheless, most of the areas visited by D2 had never previously been explored.

8.2 Canyons

8.2.1 Geological Setting

The canyon dives all consisted of an initial transit over a soft-sedimented floor before proceeding to the nearby canyon wall. The majority of each dive was spent ascending a hard or lightly-sedimented surface, broken occasionally by intermediate terraces with thicker sediment accumulation. The canyon floors were blanketed in a thick layer of silty-sand, punctuated by isolated blocks of lithified material that had fallen from the walls above. On all of the dives, the dominant canyon wall lithology was calcareous mudstone, with carbonate content sufficient to give the walls a chalky texture. This unit is likely the Late Cretaceous to Early Eocene chalk observed during previous expeditions (e.g. CANEX, EX-13-04 Legs 1 & 2). At Hendrickson Canyon and the unnamed canyon east of Veatch Canyon, the team observed a contact between the underlying calcareous unit and an overlying red-brown siliciclastic mudstone layer at about 1,465 m and 1,385 m, respectively. This lack of consistency in depth and occurrence suggests the mudstone layer may not be laterally continuous along the U.S. Atlantic margin. At the greatest depths in Nantucket Canyon (1,825 m), we encountered an underlying sandy mudstone not observed on any of the other dives. A variety of slope failure features were observed throughout the canyons, including debris aprons, talus slopes, micro- and macro-scale fractures often eroded out as slide chutes, and evidence of sharp break-off planes resulting in rock falls. There was evidence of major and minor brittle failure in nearly all of the observed canyons. An exception was Ryan Canyon, which was heavily cemented and seemingly undisturbed. A geological highlight of the canyon exploration was the discovery of an extensive series of deeply-eroded caves above a more resistant chalk layer in an unnamed canyon east of Veatch Canyon; these features were referred to by participating biologists as the “Octopus Grotto'', as many caves were inhabited by octopuses (both *Graneledone verucossa* and *Muusoctopus* sp.). In Nantucket Canyon, a glacial dropstone with a manganese crust was observed (**Figure 3**).

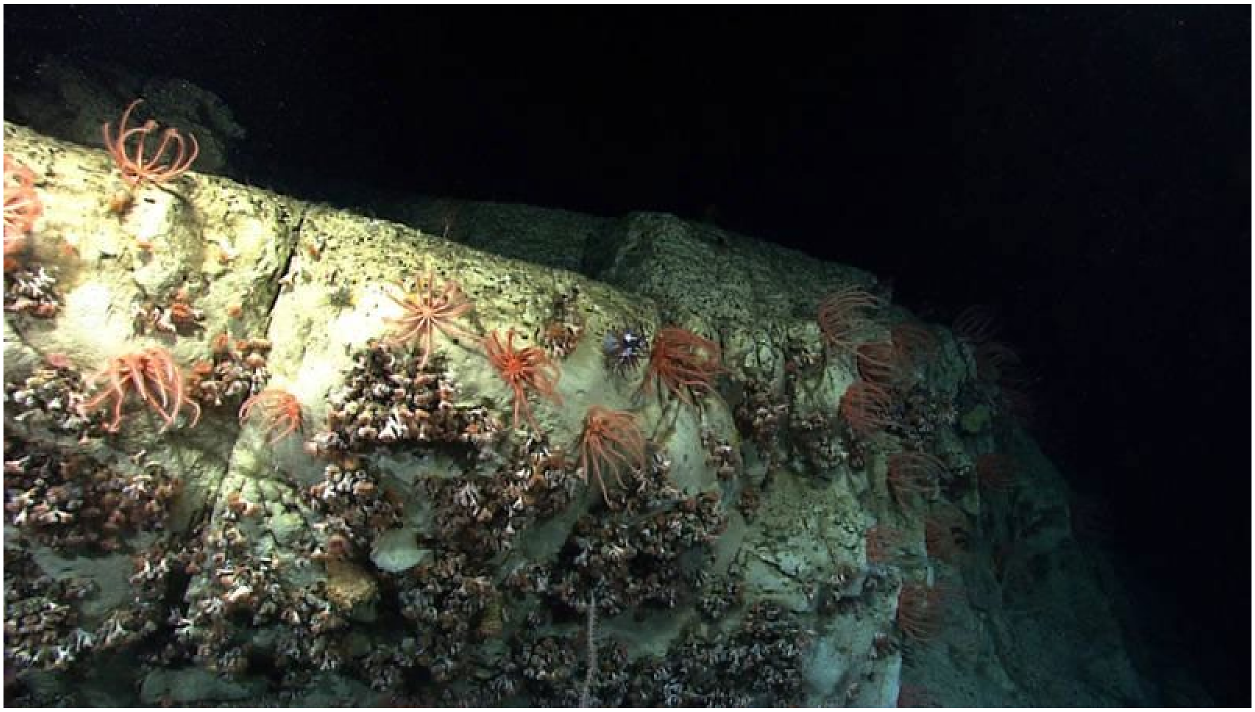

Figure 3. During the first-ever exploration of Nantucket Canyon, the ROV transited up a steep wall and discovered areas of dense populations of cup corals and brisingid sea stars.

8.2.2 Biological Setting

Biological communities in the canyons were diverse. The canyon walls were characterized by a patchy distribution of sessile fauna, likely related to stability of the walls and local current dynamics. Heavily sedimented areas (the canyon thalweg and gentle sloping walls) were populated by characteristic deep-sea, soft-bottom benthos, such as sea cucumbers (Holothuroidea), brittle stars (Ophiuroidea), and various decapods. The floor of Ryan Canyon (≈1500 m) was highly bioturbated, and thousands of very small elasipodid holothurians (?*Amperima* sp.) were scattered across the soft sediments—many were also seen swimming. Fishes were seen sporadically throughout the canyons, with a minimum estimate of at least 20 species in total; several observations were made of parasites on deepwater fish. Dominant fishes included cutthroat eels (Synaphobranchidae), grenadiers (Macrouridae), hakes (Moridae), skates (Rajiidae), and witch flounder (*Glyptocephalus cynoglossus).*

A common association observed at overhangs and below ledges was dense aggregations of *Desmophyllum* sp. cup corals, often arranged in linear fashion across the wall, with occasional colonies of the scleractinian coral *Solenosmilla* sp., the octocoral *Acanthogorgia* sp., and limid bivalves (*Acesta* sp.) among them, along with a variety of associated smaller animals (ophiuroids, crinoids, anemones, brisingid asteroids, crinoids, and hydroids); this community type has also been observed in canyons in the eastern North Atlantic.

Several invertebrate species were frequently observed during most canyon dives, particularly octocorals (at least 19 species), black corals (three species), echinoderms (sea cucumbers [Holothuroidea], brittle stars [Ophiuroidea], crinoids [Crinoidea], sea stars [Asteroidea], and sea urchins [*Hygrosoma* sp.], including some with a juvenile cusk eel [*Barathrites* sp.] tucked among the spines), octopuses (*Graneledone verrucosa*), including individuals sitting on eggs tucked under overhangs or in crevices, king crabs (*Neolithodes* sp.) and red crabs (*Chaceon* sp.), pycnogonid sea spiders, cerianthid tube anemones, glass sponges (Hexactinellida), and xenophyophores. In some places on canyon walls, *Keratoisis* sp. bamboo corals were particularly abundant.

Other notable sightings include *Muusoctous johnsonianus* (including brooding female), benthic "dandelion" siphonophores (?*Thermopalia* sp.), and at least four species of squid (*Illex illecebrosus*, *Mastigoteuthis magna*, *Brachioteuthis beanii*, and *Teuthowenia megalops*).

8.3 Seamounts

8.3.1 Geological Setting

Dives on the flanks and summits of the New England Seamount Chain revealed a diversity of lava flow morphologies and great variability in sediment cover. Those seamounts located close to the continental margin (Physalia, Retriever) were typically blanketed in a layer of hemipelagic sediment and provided only sparsely-spaced hard rock outcrops for exploration. Lavas were more extensively exposed on those seamounts beyond the EEZ, which were draped with thinner layers of fine pelagic sediments. Rough measurements of sediment thickness yielded values of > 50 cm for Retriever Seamount, compared to 5-35 cm for the seamounts further offshore. Flow types observed on the dives included sheet, lobate, and pillowed flows, with lobate being the most common morphology. A deep dive on the outer rift arm of an unnamed star-shaped seamount revealed large (50 cm to > 1 m), bulbous pillow lavas and only minimal sediment dusting. This environment was very different from that observed on the upper flanks of the other seamounts. Volcaniclastic breccias were observed at only one seamount (Physalia), where they were the dominant lithology throughout the dive. At two of the seamounts (Atlantis II and Physalia) the team observed inter-flow carbonate intervals several meters thick, perhaps indicating a hiatus in volcanic activity (**Figure 4**). All hard rock surfaces on the seamounts were covered in a layer of manganese crust displaying various surface morphologies. Crust thickness could not be measured, but was sufficient to prevent identification of the underlying rock type. During the seamount dives several isolated cobbles were observed that were likely glacial dropstones, but the team could not confirm the rock type due to the manganese crusting.

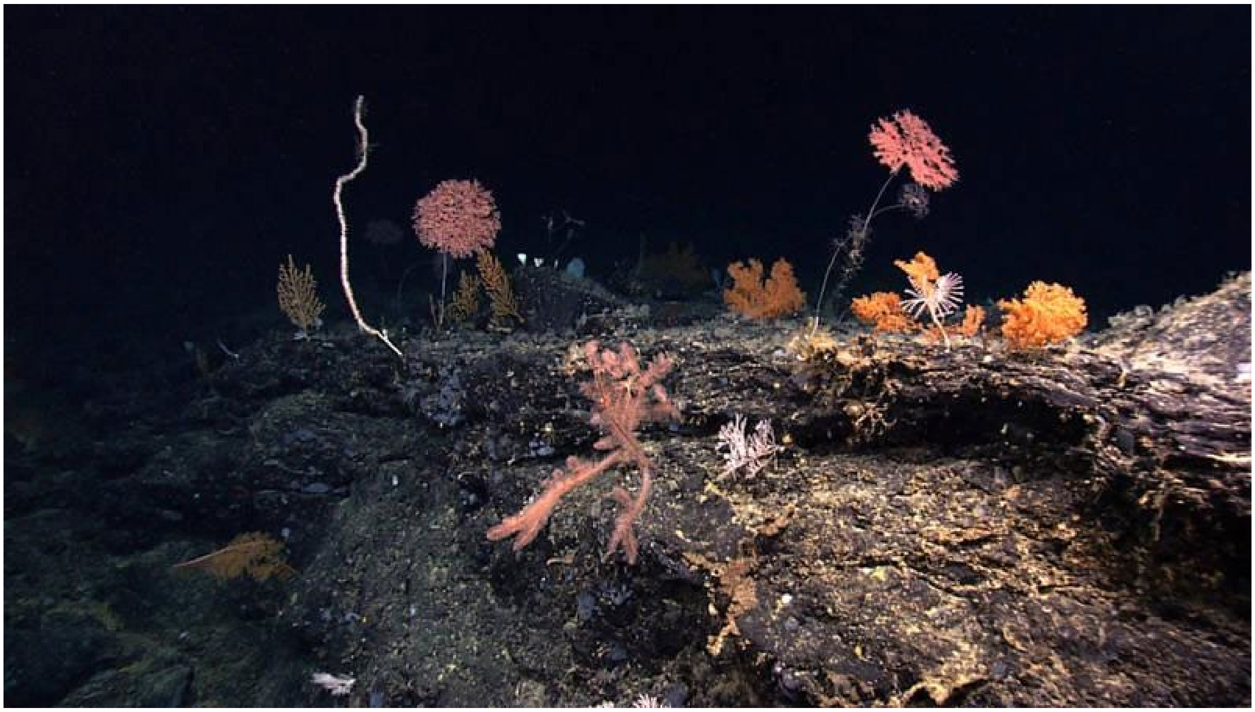

Figure 4. A spectacular hard rock area with a very high coral diversity, seen during the dive on the Atlantis II Seamount Complex. This one image has black corals, bamboo corals, and several additional octocorals, all living together to form a community.

8.3.2 Biological Setting

Biological diversity of large, observable fauna was strongly associated with the degree of sediment cover on the seamounts. As in the canyons, corals and associated fauna were very patchily distributed and more diverse in areas that were relatively sediment-free. An exception was the deepest dive (4,550-4,693 m); although the slopes of the unnamed seamount were only lightly coated with sediments, there were very few sessile fauna observed (both in terms of density and species richness) compared to shallower seamount dives, likely a result of very low food input at this depth. No fish were observed throughout the deepest dive track, however, many hexactinellid (glass) and cladorhizid (carnivorous) sponges, as well as a stoloniferous octocoral (Cornulariidae) were common. The ribbon-like colonies of the Cornulariidae were seen encrusting the seafloor throughout the deep dive, and in places their linear ribbons were relatively abundant crossing the high points of pillow lobes.

Where exposed hard substrates were available, the community could be diverse. Near the summit of Kelvin seamount a high diversity of octocorals and associated invertebrates was observed, including *Candidella* sp., *Calyptrophora ?microdentata* and *C.* ?*antilla*, *Lepidisis* sp., *Acanella* sp., *Isidella* sp., *Chrysogorgia* sp., *Iridogorgia magnispiralis* and *I. splendens* (at least some with shrimp ?*Bathypalaemonella serratipalma*), *Metallogorgia melanotrichos* (with ophiuroid associate *Ophiocreas oedipus*), *Clavularia* sp., *Cornularia*-like stoloniferan octocoral, *Paragorgia* sp., *Paramuricea* sp. (with ophiuroid *Asteroschema* sp.), *Swiftia* sp., *Corallium ?niobe,* and *Stauropathes* sp. and *Parantipathes* sp. black corals. On the northern flank of Gosnold Seamount, thickets of a bramble-like bamboo coral (*Keratoisis* sp.) formed dense patches of fine, intertwining coral branches across extensive areas of the slope. These thickets were home to a host of invertebrates, including hydroids, barnacles, galatheoid crabs, sea urchins, and glass sponges (Hexactinellida), the latter with several morphs and colors (yellow-green, purple, white). On Atlantis II Seamount, the ROV passed through a glass sponge (Hexactinellida) “zone” of high abundance and diversity beginning around 2,692 m depth.

Sea urchins (*Echinus*-like), brittle stars (Ophiuroidea) and globose xenophyophores (?Syringamminidae) were abundant on gentler, sediment-coated slopes. In addition to the many live urchins, we observed many empty tests in some locations, suggesting significant predation.

Fish diversity and abundance was relatively low in comparison to the canyon dives, with 12 species distinguished (though not specifically identified), and appeared mostly to be a subset of the species observed in the canyons. On the other hand, octocorals (at least 23 species) and black corals (at least four species) showed greater diversity on the seamounts.

8.4 Other notable highlights

On Leg 3 of the expedition, a simple tool was developed to measure sediment thickness. Dubbed the “Sepoke,” the flexible plastic rod was marked with lines at 5 cm-intervals (**Figure 5**). It could be grasped by the D2 manipulator arm and thrust into the sediment until significant resistance was met in order to get an estimate of the amount of sediment overlying the hard bottom. The Sepoke was successfully deployed on five occasions, in both canyons (Hendrickson and unnamed east of Veatch) and seamounts (Retriever, Gosnold, and Kelvin).

Input from various participating experts revealed several notable observations, including the northernmost record of purple comatulid crinoids of the genus *Xenometra* (on Kelvin Seamount) and several rare observations of asteroid sea stars. The dives provided an opportunity to witness interesting behavioral interactions that are rarely documented on video. One highlight was a pycnogonid sea spider carrying an egg mass; it is well-documented that males carry eggs, but this had not been observed in the deep sea. Several predation events were recorded, such as a hydroid colony being preyed upon by aeolid nudibranchs, *Evoplosoma* sp. sea star feeding on a bamboo coral, a neolithodid crab feeding on a *Hygrosoma* sp. sea urchin, and an unprecedented observation of a large pycnogonid sea spider (Colossendeidae) feeding on a corymorphid hydroid (giant solitary hydroid). It appeared the proboscis was specifically directed at the gonophores, suggesting feeding on reproductive tissue.

Figure 5. During EX-14-04 Leg 3, the ROV team built and tested D2's new probe to determine sediment accumulation, which was affectionately dubbed the "Sepoke" with black marks at 5 cm-intervals. Here, the Sepoke is deployed on Gosnold Seamount.

8.4.1 Partial taxon list of corals and fish (preliminary IDs requiring further analysis)

This section provides listings of all observed coral and fish during EX-14-04 Legs 2 and 3 and whether they were observed within a canyon or on a seamount. Scientific names are used along with common names of organisms when known.

Corals

Canyons: *Anthothela* sp., *Acanthogorgia* sp., bamboo corals (*Isidella* sp., *Eknomisis* sp., *Lepidisis* sp., *Keratoisis* spp., *Acanella* sp.), *Thouarella* ?*grasshoffi*, *Swiftia* sp., *Paragorgia* ?*johnsoni*, *Paramuricea* sp., stoloniferan *Clavularia* sp. and *Anthomastus* sp., chrysogorgiid whips

(*Radicipes gracilis*), sea pens (?*Anthoptilum* sp., *?Distichoptilum* sp., *Umbellula* sp., *Pennatula* sp.), and black corals (*Bathypathes* sp., *Parantipathes* sp., *Telopathes* sp.).

Seamounts: octocorals (*Anthomastus* sp., *Anthoptilum* sp., *Pennatula* sp., *Candidella* sp., *Calyptrophora ?microdentata* and *C.* ?*antilla*, *Chrysogorgia* sp., *Iridogorgia magnispiralis and I. splendens*, *Metallogorgia melanotrichos*, *Clavularia* sp., *Cornularia*-like stoloniferan octocoral, *Paragorgia* sp., *Paramuricea* sp., *Swiftia* sp., *Corallium ?niobe, Corallium ?bathyrubrum*, bamboo corals *Lepidisis* sp., *Acanella, Isidella* [at least two species], and *Jasonisis* sp.), black corals (*Telopathes* sp., *Bathypathes* sp., *Stauropathes* sp., *Parantipathes* sp.), and stony corals (*Caryophyllia* sp.).

Fish

Canyons: witch flounder (*Glyptocephalus* sp.), blue hake (*Antimora rostrata*), long-finned hake (*Urophycis chesteri*), cutthroat eels (*Synaphobranchus* sp.), duck-billed eel (*Nettastoma* sp.), ophidiid cusk eels (*Luciobrotula* sp., *Barathrites* sp., and *Dicrolene* sp.), Halosaur (*Aldrovandia* sp.), roundnose grenadier (*Coryphaenoides* sp.) and marlinspike grenadiers (*Nezumia* sp.), cusk eels (Ophidiidae), fathead (*Cottunculus* sp.), false boarfish (*Neocyttus helgae*), blackspot sea snail (*Paraliparis copei*), rockling (?*Gaidropsarus* sp.), black dogfish (*Centroscyllium fabricii*), ghost cat shark (?*Apristurus* sp.), chimaera (*Hydrolagus* sp.), skates (*Bathyraja* sp.), and dragonfish (Stomiidae).

Seamounts: Blue hake (*Antimora rostrata*), hatchetfish, ?synaphobranchid eel, halsosaur (*Aldrovandia* sp.), grenadiers (*Coryphaenoides* ?*armatus* and ?*Malacocephalus* sp.), cusk eels (?*Brotulataenia* or ?*Diplocanthopoma* and other), anglerfish [sea toad] (*Bathychaunax roseus*); snailfish (Liparidae), bristlemouth (*Gonostoma* sp.), and chimaera (*Hydrolagus affinis*).

8.5 High-resolution Mapping Characterization

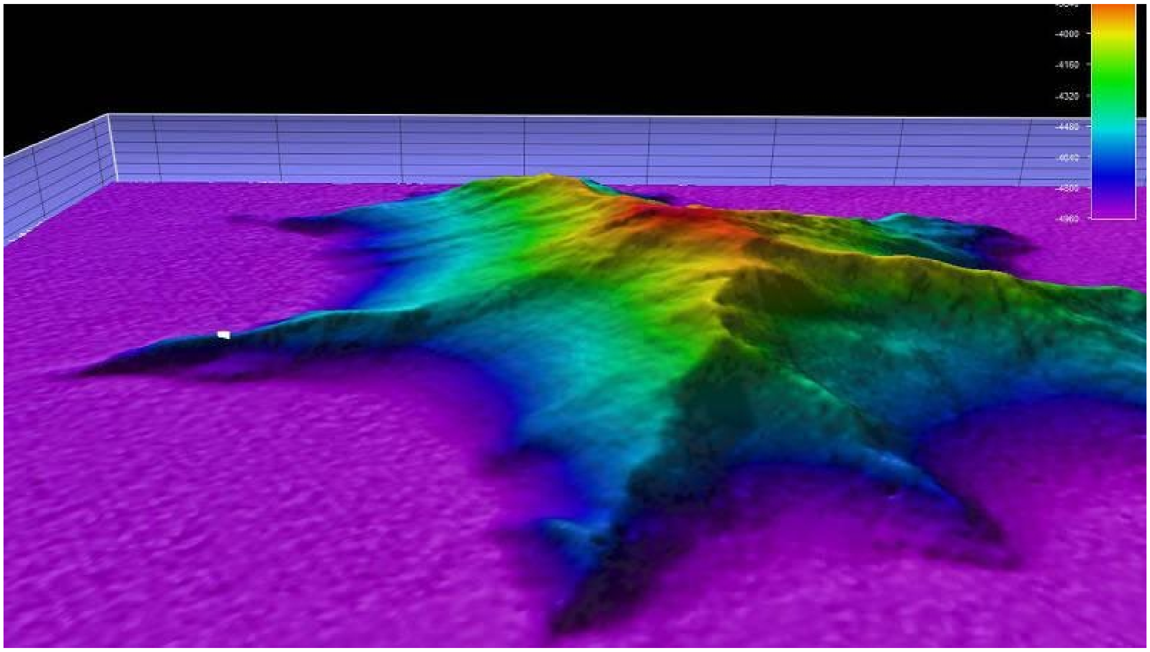

Figure 6. This image shows a side view, two-times vertical exaggeration, of the "Unnamed Deep Seamount" explored during Dive 10. The white dot represents the point where D2 was deployed.

The first leg of this expedition was a shakedown cruise that was conducted from August 9-30, 2014, and involved the completion of high-resolution multibeam sonar mapping of six seamount features within the New England Seamount Chain. The first several days of the expedition were dedicated to testing and calibrating mission-critical mapping and communication systems that were upgraded during a summer in-port maintenance period.

The rest of the expedition focused on completing high-resolution mapping of Panulirus, Gosnold, Sheldrake, Gregg, and San Pablo Seamounts. Mapping of approximately half of the Manning Seamount complex was also completed (**Figure 6**). Water column and seafloor backscatter data, and sub-bottom sonar data, were also collected 24 hours per day during mapping operations. Mapping work had to be suspended two days earlier than planned, due to the arrival of Hurricane Cristobal.

During EX-14-04 Legs 2 & 3, a number of unfavorable weather days prevented the team from conducting all scheduled ROV dives. Fortunately, the team was quickly able to adapt to changing conditions and shift to mapping operations. *Okeanos Explorer* collected over 15,000 km^2 (**Table 5**) during these two legs.

All mapping data collected during these expeditions are available in NOAA's public data archives within 60-90 days of the conclusion of the cruise, and can be accessed via the OER Digital Atlas (https://www.ncei.noaa.gov/maps/oer-digital-atlas/mapsOE.htm, last accessed August 2020).

9. References

Kennedy, B.R.C. (2014) Project Instructions for NOAA Ship Okeanos Explorer EX-14-04 Leg II and III: Our Deepwater Backyard: Exploring the Atlantic Canyons and Seamounts, Leg II (ROV and VIPs) September 4-10, 2014, Leg III (ROV, mapping, CTD) September 16-October 7, 2014. NOAA Office of Ocean Exploration and Research, Silver Spring, MD 20910. Retrieved from: https://repository.library.noaa.gov/view/noaa/859

Kennedy, B.R.C., Cantwell, K., Malik, M., Kelley, C., Potter, J., Elliott, K., Lobecker, E., Gray, L.M., Sowers, D., White, M.P., France, S.C., Auscavitch, S., Mah, C., Moriwake, V., Bingo, S.R.D., Putts, M., and Rotjan, R.D. (2019). The Unknown and the Unexplored: Insights into the Pacific Deep-sea Following NOAA CAPSTONE Expeditions. *Frontiers in Marine Science*, *6*(480). doi: 10.3389/fmars.2019.00480

Loebecker, E., and Candio, S. (2020). Mapping data acquisition and processing summary report: EX-14-04 Leg 2. Our Deepwater Backyard: Exploring the Atlantic Canyons and Seamounts (ROV and VIPs). NOAA Expedition Report. NOAA Institutional Repository. Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. doi: 10.25923/sq7c-ma04

McKenna, L.A., and Kennedy, B.R.C. (2015). Mapping data acquisition and processing report, cruise EX-14-04 Leg III : Exploring Atlantic canyons and seamounts (ROV and Mapping), September 16 to October 7, 2014 Baltimore, MD - N. Kingston, RI. NOAA Expedition Report. NOAA Institutional Repository. Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. doi: 10.7289/V5/MDR-OER-EX1404L3

National Oceanic and Atmospheric Administration (2011). Workshop Summary: NOAA Workshop on Systematic Telepresence-Enabled Exploration in the Atlantic Basin. Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. Retrieved from: https://oceanexplorer.noaa.gov/about/what-we-do/media/atl-basin-workshop-2011-summary.pdf

National Oceanic and Atmospheric Administration (2013). Northeast U.S. Canyons Expedition 2013. Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. Retrieved from: https://oceanexplorer.noaa.gov/okeanos/explorations/ex1304/welcome.html

Quattrini, A.M., Nizinski, M.S., Chaytor, J.D., Demopoulos, A.W.J., Roark, E.B., France, S.C., Moore, J.A., Heyl, T., Auster, P.J., Kinian, B., Ruppel, C., Elliott, K.P., Kennedy, B.R.C., Lobecker, E., Skarke, A., Shank, T.M.. (2015). Exploration of the Canyon-Incised Continental Margin of the Northeastern United States Reveals Dynamic Habitats and Diverse Communities. *PLoS One*, *(10)*10: e0139904. doi: 10.1371/journal .pone.0139904

Sandwell, D.T., Müller, R.D., Smith, W.H.F., Garcia, E., and Francis, R. (2014). New global marine gravity model from CryoSat-2 and Jason-1 reveals buried tectonic structure. *Science*, *346*(6205), 65-67. doi: 10.1126/science.1258213

10. Appendix

10.1 Appendix A: Acronyms

ACUMEN—Atlantic Canyons Undersea Mapping Expeditions
AERONET—NASA Aerosol Robotic Network
BOEM—Bureau of Ocean Energy Management
CCOM—Center for Coastal and Ocean Mapping
CIOERT—Cooperative Institute for Ocean Exploration, Research & Technology
CTD—Conductivity, temperature, and depth
D2—ROV *Deep Discoverer*
DO—Dissolved oxygen
DOC—Department of Commerce
EEZ—Exclusive Economic Zone
FAU—Florida Atlantic University
FSU—Florida State University
FSU CML—Florida State University Coastal Marine Laboratory
GDIT—General Dynamics Information Technology
HBOI—Harbor Branch Oceanographic Institute
HAPC—Habitat area of particular concern
ISC—Inner Space Center
kHz—Kilohertz
km—Kilometers
LSS—Light scattering spectroscopy
LSU—Louisiana State University
MAN—NASA Maritime Aerosol Network
MARCO—Mid-Atlantic Regional Council on the Ocean
MMPA—Marine Mammal Protection Act
MPA—Marine protected area
NASA—National Aeronautics and Space Administration
NCCOS—NOAA National Centers for Coastal Ocean Science
NCDDC—NOAA National Coastal Data Development Center
NCEI—NOAA National Centers for Environmental Information
NEPA—National Environmental Policy Act
NMFS—NOAA National Marine Fisheries Service
NOAA—National Oceanic and Atmospheric Administration
NOC—National Oceanography Centre
NOS—NOAA National Ocean Service
NROC—Northeast Regional Ocean Council
NSU—Nova Southeastern University
OEAWG—Ocean Exploration Advisory Working Group

OER—NOAA’s Office of Ocean Exploration and Research
OET—Ocean Exploration Trust
OMB—Office of Management and Budget
ONMS—NOAA Office of National Marine Sanctuaries
ORP—Oxygen reduction potential
OSU—Oregon State University
ROV—Remotely operated vehicle
SBNMS—Stellwagen Bank National Marine Sanctuary
SIS—Seafloor Information System
SRF—Science and Research Fund
TSG—Thermosalinograph
UCAR—University Corporation for Atmospheric Research
UConn—University of Connecticut
UH—University of Hawai‘i at Mānoa
ULL—University of Louisiana at Lafayette
UMES—University of Maryland Eastern Shore
UNC—University of North Carolina
UNH—University of New Hampshire
URI—University of Rhode Island
USGS—U.S. Geological Survey
USNM—National Museum of Natural History
WHOI—Woods Hole Oceanographic Institution
XBT—Expendable bathythermograph